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Abundance and diversity patterns of the sessile macrobenthic community associated with environmental gradients in Vitória Harbor, southeastern Brazil

Ilana Rosental Zalmon[1,4]**; Werther Krohling**[2] **& Carlos Eduardo Leite Ferreira**[3]

[1] *Laboratório de Ciências Ambientais, Universidade Estadual do Norte Fluminense. Avenida Alberto Lamego 2000, 28013-602 Campos dos Goytacazes, RJ, Brazil.*
[2] *Laboratório de Ecologia Terrestre e Aquática, Centro Universitário Vila Velha. Rua Comissário José Dantas de Melo 21, 29101-770 Vila Velha, ES, Brazil.*
[3] *Laboratório de Ecologia e Conservação de Ambientes Recifais, Departamento de Biologia Marinha, Universidade Federal Fluminense. Rua Outeiro São João Batista, 24020-141 Niterói, RJ, Brazil.*
[4] *Corresponding author. E-mail: ilana@uenf.br*

ABSTRACT. Harbor terminals and urban sewage effluents affect the composition and distribution of epibenthic organisms. In this study, we hypothesized that the benthic community structure at the Vitoria Harbor changes spatially in a ~3 km scale, and that these changes are associated with environmental gradients resulting from point-source sewage and differences in the physical and chemical parameters of the water along the harbor access channel. Four sites, internal (PI), intermediate-internal (PMI), intermediate-external (PME) and external (PE), varying from 0.5 to 4.0 km off the harbor, were sampled on five quadrats at six sampling dates (N = 30 per site). The epibenthic community on the shallow sublitoral rocky shore was sampled fortnightly from December 2005 to February 2006 by point-intersection method. A total of 27 taxa were registered with higher richness and diversity values at the external sites. The similarity analysis indicated two distinct systems, with the internal sites PI and PMI apart from the external PME and PE, which showed 97% of dissimilarity. While the internal sites presented some estuarine characteristics and a high coverage (> 60%) of hydrozoans and bryozoans with silt/clay, the external ones showed coastal water influence and higher amounts of sedimentary material substrate (> 50%). This pattern reflects the estuarine gradient and the suspended sedimentary material at the internal sites, which is carried out to the external parts of the channel. The data showed two distinct benthic communities and support the hypothesis that the community structure varies along the harbor access channel in a gradient from the inner to the outer portion of the estuary.

KEY WORDS. Epibenthic community; environmental gradient; estuary; sedimentation.

Rocky shore benthic communities associated with coastal areas located near or at urban and industrial centers are subject to human impacts (Carlton 1996, Crowe *et al.* 2000, Jackson 2001, Jackson *et al.* 2001, Vallarino *et al.* 2002, Bax *et al.* 2003). These shores support a rich biodiversity, but exposure to impacts such as contamination by heavy metals and/or bacteria, nutrients from organic or industrial pollution from diverse sources and from sedimentation (Jickells 1998, Loureiro *et al.* 2001, Boer & Prins 2002, Wolf & Backeljau 2004, Sterza & Fernandes 2006) seriously affect the diversity and functioning of these ecosystems. In these impacted coastal environments, the abundance and composition of marine communities are altered at different spatial and temporal scales, as organisms that can tolerate stress are selected at the expense of others (Warwick & Clarke 1991, Thompson *et al.* 2002, Airoldi 2003). Consequently, it is important to monitor these coastal environments for changes in macrobenthic communities resulting either from natural sources or from anthropogenic influences (Clarke & Warwick 2001, Grall & Chauvaud 2002).

Large harbors are common along the Brazilian coast, mainly in the Southeast. The estuarine system of Vitoria Bay, adjacent to the Espírito Santo Bay, has endured great anthropological impact over the years, receiving large daily volumes of domestic and industrial sewage, and effluents from the port system (Sterza & Fernandes 2006). Organic pollution interacts with other chronic forms of pollution (heavy metals and hydrocarbons) from the industries located in the surrounding municipalities (Jesus *et al.* 2004, Joyeux *et al.* 2004a) such as Vila

Velha, Cariacica and Vitória. With a population of approximately 962,000 inhabitants (IBGE 2000), these municipalities also release untreated sewage in the ocean.

Season and water regimen (rainy season: December to March) are associated with differences in the physical and chemical characteristics of water bodies, leading to local variations in the seasonal patterns of organic and inorganic nutrient discharges. These patterns are directly related to the input of domestic sewage (Carmouze 1994). Recent studies have revealed a physical and chemical gradient in the Vitoria's harbor estuary: the inner region has higher average temperatures, whereas more peripheral areas have higher levels of salinity, transparency, dissolved oxygen and higher pH (Sterza & Fernandes 2006).

Studies to characterize and monitor the environment at the Vitoria harbor using a defined experimental design are scarce. The primary goal of the few available studies is to meet the environmental restrictions proposed by the State Institute of the Environment-IEMA, or to serve the industries that use the harbor region in their activities. The levels of heavy metals in the sediment (Grall & Chauvaud 2002), the distribution of ichthyoplankton communities (Joyeux *et al.* 2004a, b, Chagas *et al.* 2006), the benthic communities in unconsolidated substrate (Nalesso *et al.* 2005), and the distribution patterns of estuarine zooplankton (Sterza & Fernandes 2006, Fernandes *et al.* 2005) have been recently investigated.

Given the lack of information regarding the epibenthic organisms and their importance as environmental bioindicators, the main objective of this study was to characterize the subtidal rocky benthic communities along the Vitoria Harbor. Also, we correlate the attributes of the biotic community with the water parameters (pH, salinity, temperature, transparency, dissolved oxygen, and inorganic nutrients, as nitrite, nitrate, ammonia, total nitrogen, phosphate, total phosphorus, which are dispersed in situ along the estuary). We tested the hypothesis that community composition and structure varies spatially along the harbor access channel, following an environmental gradient from the inner to the outer portion of the estuary. According to Sterza & Fernandes (2006), the outer channel is subject to better conditions in terms of environmental stability of the physico-chemical parameters of the water column (mainly salinity, dissolved oxygen and transparency), and is less affected by the organic load. Thus, we should expect a higher epibenthic richness and diversity in the outermost sectors, where conditions are more stable.

MATERIAL AND METHODS

The Vitoria Bay is located in the state of Espirito Santo, southeastern Brazil; the water flows east into the Espirito Santo Bay, and then into the open ocean (Fig. 1). The bay is surrounded by mangroves, muddy beaches, rocky shores and artificial substrates (pillars, bridges and wharves). The southern portion of the Vitoria Bay has an area of about 14.5 km², where the Vitoria Harbor is located (20°19'S, 40°20'W), with a dockside area of 4.4 km². The harbor channel is approximately 9 km long, with a maximum depth of about 23 m and an average tidal range of 0.8 m (Division of Hydrography and Navigation, http://www.dhn.mar.mil.br).

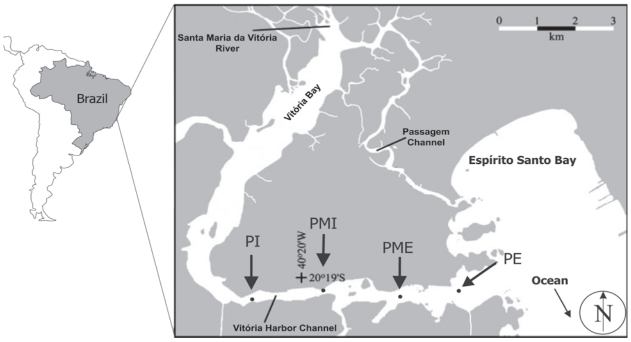


Figure 1. Location of the Vitória Bay and the four study stations along the Vitória Harbor channel: (PI) Internal Station, (PMI) Internal Midpoint (SME), External Midpoint and (EP) External Station.

The main contribution of the continental water comes from the Santa Maria da Vitoria River, in the inner portion of the estuary. The inland waters have typical continental characteristics (higher temperature, lower pH and dissolved oxygen), whereas the outer portion of the estuary is characterized by coastal waters (lower temperature, higher values of dissolved oxygen, pH and transparency) (Sterza & Fernandes 2006, Joyeux *et al.* 2004b). The average rainfall is markedly seasonal, with periods of greater precipitation during the summer months, and lower in winter.

With the expansion of the oil industry in the region, maritime traffic has intensified with the presence of supply boats, which support the drill ships and oil rigs. Furthermore, there has been an increase in dredging activities for deepening the navigation channel to allow larger ships to enter.

Along the harbor channel, the area receives discharges from several smaller bodies of water along with the drainage flowing into the port. Four stations were sampled in the inner and outer channel (Fig. 1). The innermost stations (PI and PMI) receive a direct influence of flowing water river and domestic sewage input. The outermost stations (PME and PE), by contrast, are influenced by coastal waters. The stations are approximately 2 km apart from one another. Due to the tidal movements, all stations are subject to the influence of domestic sewage.

From December 2005 to February 2006 (rainy season: December to March) our water samples were obtained biweekly at each station using a Van Dorn bottle (N = 24 samples/station). The following water data were obtained in situ (2-3 m deep): pH, salinity, temperature and dissolved oxygen with a Horiba multiparameter meter and surface water transparency by Secchi disc. Simultaneously, we collected water samples with the Van Dorn bottle for nutrient analysis (nitrite, nitrate, ammonia, total nitrogen, phosphate, total phosphorus) according to Carmourze (1994) and Clesceri *et al.* (1995).

Samplings for subtidal benthic community were obtained by SCUBA (W. Krohling) using a 30 x 30 cm quadrat with the non-destructive point intersection technique (Sutherland 1974). On each sampling date, five sampling units were taken at each station, from the same rocks, between 3-5 m deep. This depth was chosen to ensure our safety while diving (there is little or no visibility below five meters), and to allow us to sample subtidal organisms (at low tide intertidal organisms could occur between 0-2 m depth). A total of 30 samples (N = 5 quadrats on six sampling date) were collected at each station along the harbor channel.

The benthic community was evaluated for taxonomic composition, species richness, relative abundance (mean percent cover of each taxon in the five quadrats on six sampling date: N = 30), Brillouin diversity for relative data as percentage cover, and Simpson dominance (Magurran 1988). Spatial differences in the community structure indicators and the environmental parameters monitored were tested using one-way variance analysis for repeated measures (ANOVA-RM) with $\alpha = 0.05$, given that the same sites and sampling rocks were examined, followed by a Tukey test (Zar 1999). The normality and homogeneity of variances of the data was tested a priori using Shapiro-Wilk W and Cochran test, respectively. The values were $\sqrt{}$arcsen X transformed to minimize heteroscedasticity (Zar 1999).

The comparative analysis of the benthic community at the four study stations included a multi-dimensional scaling (MDS) with Bray-Curtis similarity coefficient for percentage data. The adequacy of the configuration of the samples for MDS was obtained from stress value (Clarke & Warwick 2001). The ANOSIM permutation test (one way) was used to evaluate the significance of the differences among stations. The similarity matrices included the percentage cover of the organisms present at each quadrat and station; each quadrat was treated separately to increase the permutations possibility and, consequently, the power of the test (Clarke & Warwick 2001). The similarity percentages procedure (SIMPER) defined the contribution of the most abundant taxa between and within groups for the MDS procedure (Clarke & Warwick 2001). Data analysis was performed with PRIMER 6 software.

The water parameters and inorganic nutrients were correlated with the biological data matrix, which included the taxa with > 5% coverage in at least one quadrat using a canonical correlation analysis (CCA) with the software MVSP 3.13.

RESULTS

Environmental parameters

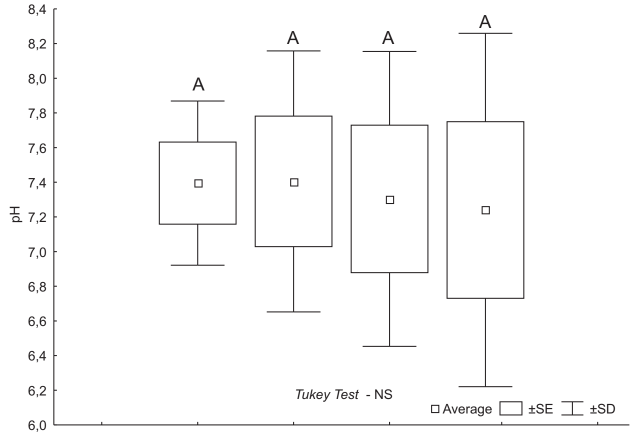
The pH ranged between 7.2 and 7.4 (Fig. 2), with no significant differences among the four study stations (Tab. I). Salinity showed an increasing trend (22 to 28 psu) toward the outermost station (Fig. 3), but with no significant differences (Tab. I). The temperatures were significantly higher at PI, PMI and PME (Fig. 4, Tab. I). The innermost PI and PMI showed significantly less transparency when compared with the others (Fig. 5, Tab. I). Dissolved oxygen showed increasing values toward the outermost station (ranging from 5.5 mg/l to 7.5 mg/l), with PE significantly higher than the others (Fig. 6, Tab. I).

The average values of total phosphorus and phosphate ranged between 0.08 to 0.21 mg/l and 0.01 to 0.03 mg/l, respectively, with higher values at the outermost stations, but with no significant differences (Figs 7 and 8, Tab. I). Average values of ammonium ranged from 0.05 and 0.10 mg/l, with no significant differences (Fig. 9, Tab. I). The concentrations of nitrite, nitrate and total nitrogen showed mean values decreasing toward the outermost station of the channel (Figs 10-12), being significantly lower at PE for nitrate and total nitrogen, 4.87 and 5.37 mg/l, respectively (Tab. I).

Table I. Analysis of variance. F and p values for environmental parameters related to the four study stations (N = 24 samples/station).

Variable	SS	df	MS	SS	df	MS	F	p
pH	0.0739	3	0.02465	7.6609	12	0.63841	0.038607	0.989 NS
Salinity	65.3856	3	21.79519	147.3670	12	12.28058	1.774768	0.205 NS
Temperature	22.1089	3	7.36965	16.4849	12	1.37374	5.364642	0.014 *
Transparency	0.7092	3	0.23640	0.5789	12	0.04824	4.900690	0.019 *
DO	12.0437	3	4.01456	13.6373	12	1.13644	3.532564	0.048 *
Ammonium	0.0139	3	0.00464	0.1540	12	0.01284	0.361215	0.782 NS
Total phosphorus	0.0333	3	0.01110	0.0954	12	0.00795	1.393514	0.292 NS
Total phosphate	0.0008	3	0.00030	0.0045	12	0.00037	0.742207	0.547 NS
Nitrate	107.5367	3	35.84556	80.2724	12	6.68936	5.358590	0.014 *
Nitrite	0.0001	3	0.00004	0.0003	12	0.00002	2.000000	0.168 NS
Total nitrogen	131.6640	3	43.88799	136.1075	12	11.34229	3.869410	0.038 *

* $p < 0.05$, NS = not significant.



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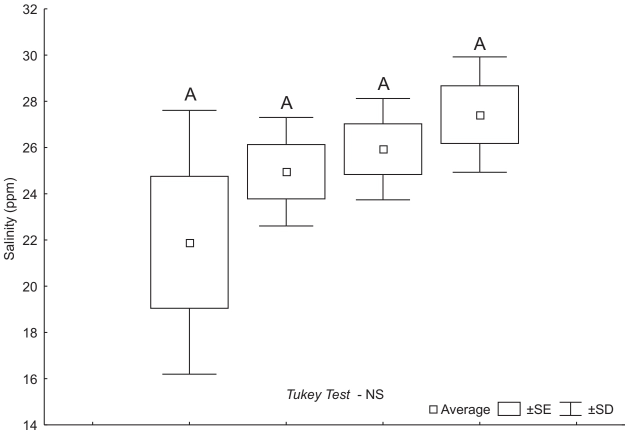

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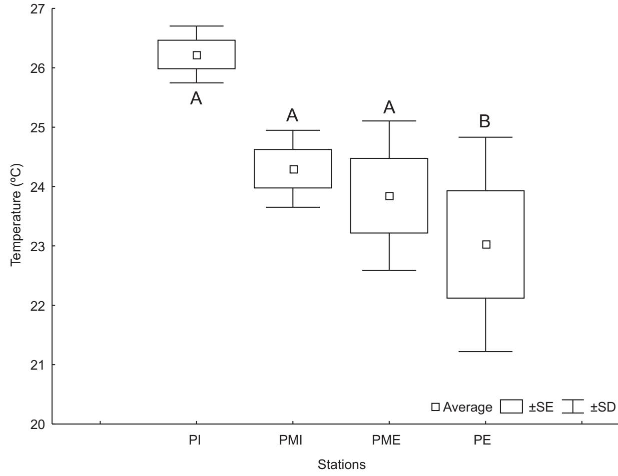

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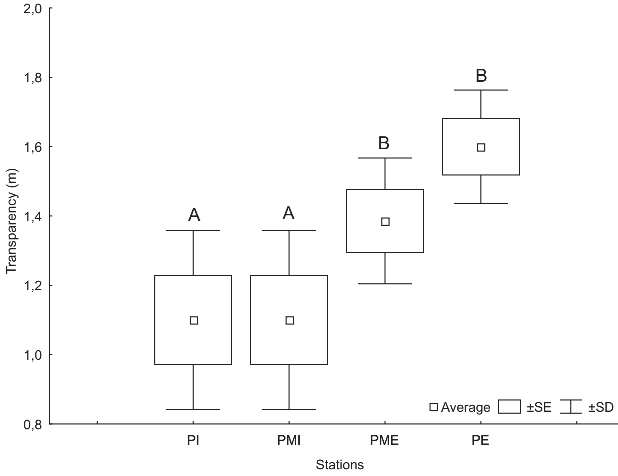

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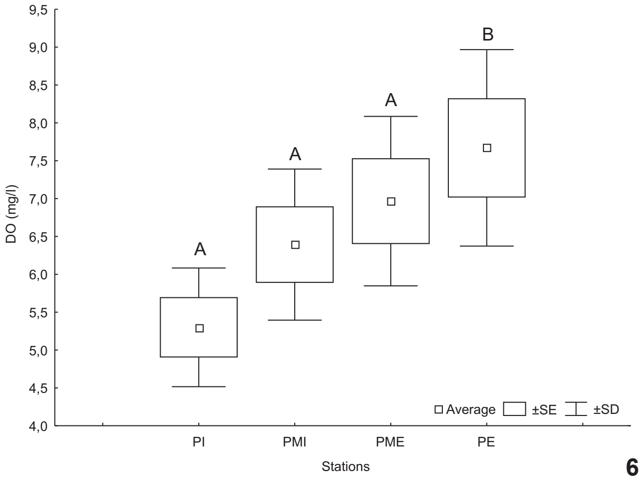

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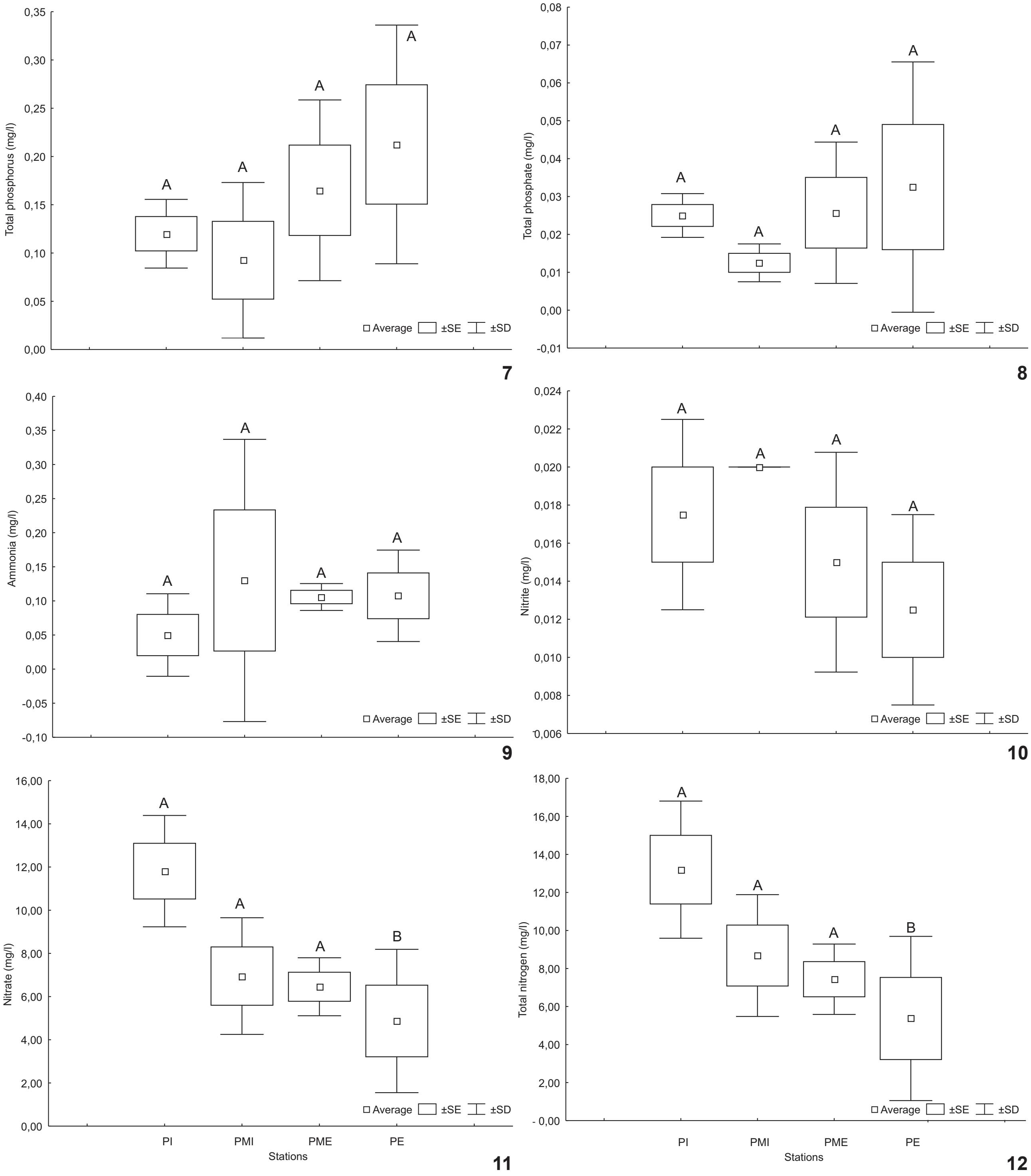
Figures 2-6. Mean values, error (EP) and standard deviation (SD) of the environmental parameters of six samples monitored at the four study stations PI (Internal Station), PMI (Internal Midpoint), PME (External Midpoint) and PE (External Station) along the Vitória Harbor. The letters A and B indicate homogeneous groups (nonparametric Tukey Test, $p < 0.05$).



Figures 7-12. Mean values, error (EP) and standard deviation (SD) of six samples of inorganic nutrients in the four study stations PI (Internal Station), PMI (Internal Midpoint), PME (External Midpoint) and PE (External Station) along the Vitória Harbor. Letters A and B indicate the homogeneous groups (nonparametric Tukey Test, $p < 0.05$).

Benthic community

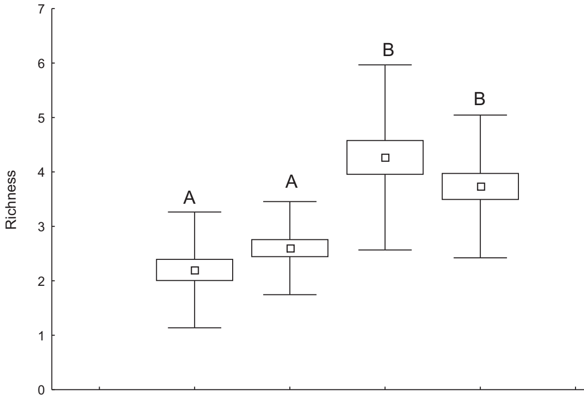
A total of 27 taxa belonging to the phyla Porifera, Cnidaria, Annelida, Ectoprocta, Crustacea, Echinodermata and Tunicata were recorded (Tab. II). Also, there was a sedimentary material about 4 cm thick tightly associated with hydrozoans Bougainvillidae, and arborescent bryozoans Bugulidae, which was designated as "aggregate". At PI and PMI, the percentage coverage of this aggregate was > 60%, whereas at PME and PE, sediment without macrobenthic organisms was present in > 55% of the substrate covering the organisms. The most representative taxa (> 5% coverage in at least one station) were *Carijoa riisei* (Duchassaing & Michelotti, 1860), *Tridentata distans gracilis* (Hassall, 1853), *Sertularia marginata* (Kirchenpauer, 1864), *Tedania ignis* (Duchassaing & Michelotti, 1864) and *Hymeniacidon heliophila* Parker, 1910. Only *C. riisei* was present at all stations. PME had the highest total and average richness of taxa (Tab. I, Figs 13-15) with significant higher values at the outermost stations (Tab. III). Exclusive taxa were recorded at PI: *Astrangia* sp., Demospongiae sp. 1 and *Cliona dioryssa* de Laubenfels, 1950; at PMI: *Diphasia* sp. At PME: *Clathrina aurea* Solé-Cava, Klautau, Boury-Esnault, Borojevic & Thorpe, 1991, *Mycale angulosa* (Duchassaing & Michelotti, 1864), *Megabalanus tintinnabulum* (Linnaeus, 1758), *Echinaster brasiliensis* (Uller & Troschel, 1880), *Lytechinus variegatus* (Lamarck, 1816) and *Distaplia* sp. and at PE: *T. distans gracilis*, *Schizoporella* sp. and *Scrupocellaria cornigera* (Pourtales, 1863).

The community structure descriptors differed significantly among the stations (Tab. III). The average taxa richness was significantly higher at PE and PME, with three and four taxa, respectively (Fig. 13). The Brillouin diversity had significantly higher mean values at PE (Fig. 14, Tab. III), whereas the Simpson dominance was significantly lower at PE than at the others stations (Fig. 15, Tab. III).

Multivariate analyses (MDS) revealed two distinct groups, characterizing two different faunal groups, one at PI and PMI and the other at outermost stations PME and PE (Fig. 16). The stress value was low (0.11) and indicates a good graphic representation. The ANOSIM similarity analysis revealed a significant difference among the four stations (R = 0.762, P: 0.1%).

The SIMPER analysis showed that the "aggregate" of hydrozoans + bryozoan and the sponges *T. ignis* and *H. heliophila* contributed most to the similarity (54%) of Group I, which included the innermost stations PI and PMI (Tab. IV). In Group II (the outermost stations PME and PE), the octocoral *C. riisei*, the colonial tunicate *Didemnun rodriguesi* Rocha e Monniot, 1993 and the hydrozoan *Dynamena disticha* (Bosc, 1802) were the main components for the 27% similarity (Tab. IV). The dissimilarity >95% between inner and external stations was mainly due to the aggregate and *T. ignis* (Group I) and *C. riisei* (Group II) (Tab. IV).

The canonical correlation analysis confirmed the formation of two groups (Fig. 17). Axis 1 explained 75% of variation, featuring two distinct water masses, one with estuarine char-



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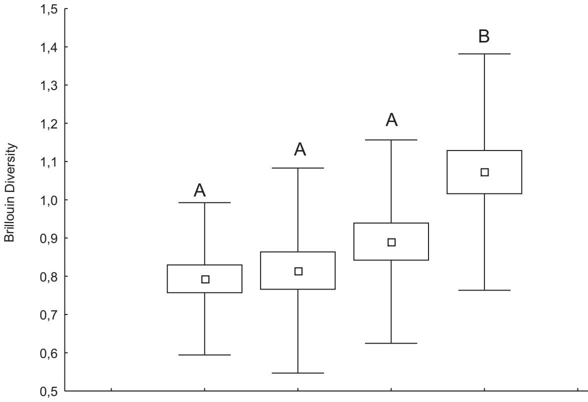

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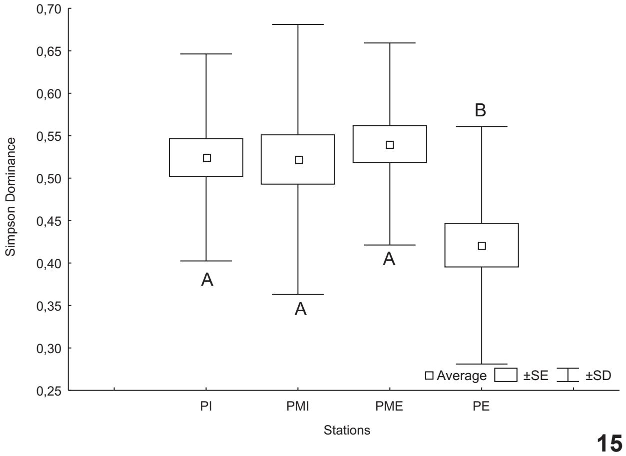

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Figures 13-15. Species richness, Brillouin diversity and Simpson dominance recorded at the four study stations along the Vitória Harbor. Mean values, standard error (EP) and standard deviation (SD) of 30 samples/station (N = 5 quadrats on six sampling dates): PI (Internal Station), PMI (Internal Midpoint), PME (External Midpoint) and PE (External Station). Letters A and B indicate homogeneous groups (nonparametric Tukey Test, p < 0.05).

Table II. Mean values of percent cover ± standard deviation for the taxa and for the sediment layer (without macrobenthic organisms) recorded at the four study stations PI (Inner Station), PMI (Inner Midpoint), PME (External Midpoint) and PE (External Station) along the Vitoria Harbor (N = 5 quadrats on six sampling date/station).

Taxa	Stations			
	PI	PMI	PME	PE
Porifera				
Demospongiae sp. 1	0.7 ± 1.6	–	–	–
Clathrina aurea Solé-Cava *et al.*, 1991	–	–	2.2 ± 4.0	–
Cliona dioryssa de Laubenfels, 1950	1.1 ± 3.4	–	–	–
Hymeniacidon heliophila Parker, 1910	3.7 ± 7.9	16. 8 ± 20.1	1.0 ± 2.5	–
Mycale angulosa (Duchassaing & Michelotti, 1864)	–	–	–	2.7 ± 4.1
Tedania ignis (Duchassaing & Michelotti, 1864)	15.9 ± 20.7	13.6 ± 14.2	–	–
Cnidaria				
Astrangia sp.	0.6 ± 1.8	–	–	–
Carijoa riisei (Duchassaing & Michelotti, 1860)	1.2 ± 2.7	0.3 ± 1.3	2.4 ± 4.7	14.9 ± 13.1
Dynamena disticha (Bosc, 1802)	–	–	3.4 ± 6.4	4.9 ± 5.8
Diphasia sp.	4.9 ± 8.1	1.2 ± 4.7	0.3 ± 1.3	–
Gorgoniidae	1.9 ± 4.1	–	–	–
Lophogorgia sp.	–	1.6 ± 4.5	–	–
Sertularia marginata (Kirchenpauer, 1864)	–	–	5.1 ± 7.5	2.2 ± 5.1
Tridentata distans gracilis (Hassall, 1853)	–	–	–	6.7 ± 10.9
Ectoprocta				
Schizoporella sp.	–	–	–	0.3 ± 1.8
Scrupocellaria cornigera (Pourtales, 1863)	–	–	–	3.6 ± 5.1
Annelida				
Megalloma sp.	0.6 ± 1.5	–	0.7 ± 1.4	–
Arthropoda				
Megabalanus tintinnabulum (Linnaeus, 1758)	–	0.8 ± 1.7	–	–
Echinodermata				
Echinaster brasiliensis (Uller & Troschel, 1880)	–	–	1.0 ± 1.6	3.2 ± 4.2
Lytechinus variegatus (Lamarck, 1816)	–	–	2.1 ± 2.7	–
Tropiometra carinata (Lamark, 1816)	–	–	1.6 ± 2.4	–
Tunicata				
Clavelina oblonga Herdman, 1880	0.4 ± 1.2	1.0 ± 2.3	–	–
Didemnun rodriguesi Rocha e Monniot, 1993	0.4 ± 1.7	1.6 ± 3.6	4.2 ± 5.5	4.3 ± 5.9
Distaplia sp.	–	–	1.0 ± 2.2	–
Lissoclinum fragile (Van name, 1902)	–	2.3 ± 3.1	1.4 ± 2.1	1.1 ± 1.8
Polysyncraton amethysteum Van Name, 1902	–	0.6 ± 1.8	1.6 ± 2.4	–
Styela plicata (Lesueur, 1823)	–	0.3 ± 1.0	0.9 ± 1.7	–
Aggregate (Bougainvillidae + Bugulidae)	62.6 ± 18.1	60.0 ± 22.3	–	–
Total number of taxa	12	12	15	10
Sediment layer (without macrobenthic organisms)	4.8 ± 9.9	–	71.0 ± 9.0	55.9 ± 17.7

Table III. Analysis of variance. F and p values for richness, diversity and dominance variables related to the four study stations (N = 30 samples/station).

	SS	df	MS	SS	df	MS	F	p
Richness	83.4667	3	27.8222	187.7333	116	1.6184	17.1913	0.0000*
Diversity	1.4466	3	0.4822	8.0559	116	0.0694	6.9433	0.0002*
Dominance	0.2680	3	0.0893	2.1433	116	0.0185	4.8342	0.0033*

* $p < 0.05$

Table IV. SIMPER with the percentage contribution of each taxon to the similarity within and between groups from MDS analysis: PI (Inner Station), PMI (Inner Midpoint), PME (External Midpoint) and PE (External Station).

Similarity within and between groups		Intern (PI + PMI) (%)	Extern (PME + PE) (%)
Similarity within groups		54.30	27.03
Aggregate (Bougainvillidae+Bugulidae)		72.17	–
Tedania ignis		14.52	–
Hymeniacidon heliophila		6.62	–
Carijoa riisei		–	26.58
Didemnun rodriguese		–	17.90
Dynamena disticha			16.91
Sertularia marginata			8.33
Dissimilarity between groups	Intern vs Extern	96.70	
	Aggregate	23.53	
	Tedania ignis	9.76	
	Carijoa riisei	7.82	
	Hymeniacidon heliophila	6.74	
	Didemnun rodriguese	6.04	
	Dynamena disticha	5.90	

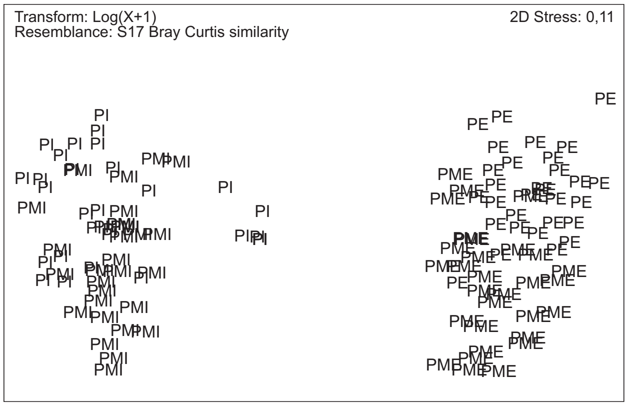

Figure 16. Multidimensional Scaling Analysis (MDS) for 30 samples/station (N = 5 quadrats on six sampling dates) on four study stations using the percent cover of each taxon on each quadrat and date: PI (Internal Station), PMI (Internal Midpoint), PME (External Midpoint) and PE (External Station) along the Vitória Harbor.

acteristics (PI and PMI) and another more coastal (PE and PME). The representative components "aggregate " (bryozoans + hydrozoans), *T. ignis*, *H. heliophila* and *C. riisei* were associated with higher values of pH, temperature, nitrite, nitrate and total nitrogen on the most inner stations PMI and PI. At the external PME and PE, the most characteristic organisms such as *D. rodriguesi*, *D. disticha*, *T. distans gracilis*, *S. marginata*, and *C. riisei* were associated with more coastal waters with higher salinity, transparency and dissolved oxygen values. The levels of total phosphorus and total phosphate were higher in these outermost stations, indicating differences in the input of nitrogen and phosphorus along the channel.

DISCUSSION

Estuaries are characterized as highly dynamic systems, with large variations in salinity, temperature, pH and nutrients following a daily cycle of tides, providing distinct regions along a characteristic gradient (FERNANDES *et al.* 2005). As transi-

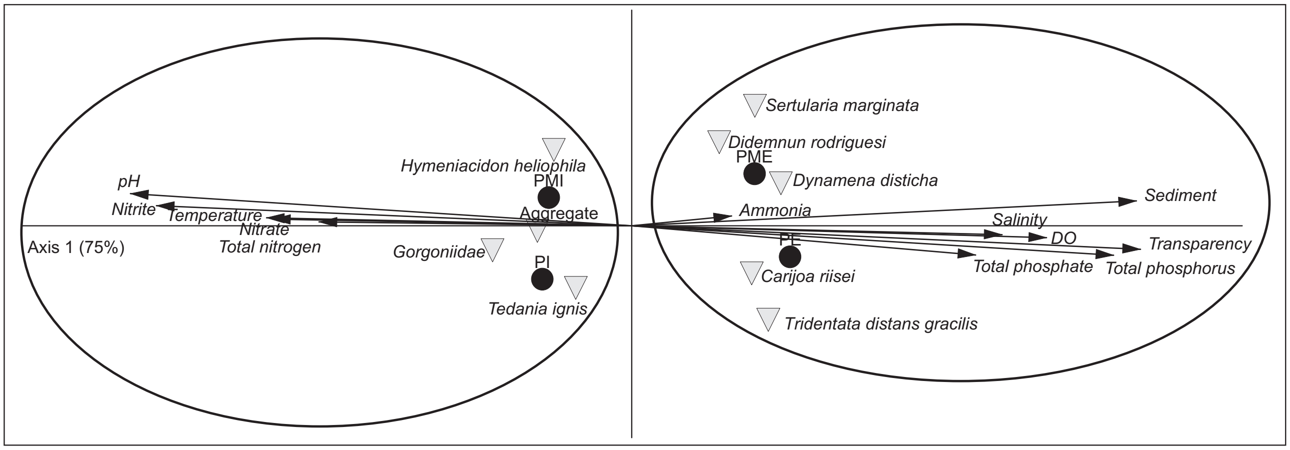

Figure 17. Canonical correlation analysis (ACC) including the representative taxa (> 5% coverage in at least one quadrat – triangles) and descriptors (environmental parameters and inorganic nutrients – arrows) for the four study stations (black circles): PI (Internal Station), PMI (Internal Midpoint), PME (External Midpoint) and PE (External Station) along the Vitória Harbor.

tional areas between coastal and inland waters, estuaries usually show well-marked gradients, with higher temperatures and organic nutrients at their inner portions, and higher levels of dissolved oxygen, transparency and salinity (Souza-Pereira & Camargo 2004) in the outer areas. Such characteristics of estuarine hydrochemistry were also recorded here, and in other studies conducted in the Vitoria Bay region (Sterza & Fernandes 2006, Joyeux *et al.* 2004b, Nalesso *et al.* 2005).

However, it is noteworthy that the highest values for phosphorus (total phosphorus and phosphate) were recorded in locations outside the study area. This may have occurred because phosphorus may get retained in marine sediments which are eventually released into the water column, a phenomenon known as "internal recycling of sediment" (Davies 2004). According to Baumgarten *et al.* (1996), biogeochemical processes occurring in sediments may alter the quality of the overlying water, which would explain the higher concentration of phosphate in the outer portions of the channel.

Low concentrations of dissolved oxygen, and great amounts of organic nutrients are characteristic of estuarine waters contaminated with domestic sewage (Mayer-Pinto & Junqueira 2003, Marques Junior *et al.* 2006, Vizzini & Mazzola 2006). This contamination contributes to environmental stress. Alterations in freshwater input are but one amongst the various anthropogenic impacts affecting the Vitoria Bay in the last half century. Changes in land-use at the watershed, filling, channeling and the input of untreated industrial and urban sewage are other examples. Environments stressed by nutrient input usually harbor low species richness and diversity (Clarke & Warwick 2001, Nalesso *et al.* 2005). Corresponding results were recorded at the innermost stations, with higher values of nitrogen, lower DO, and significantly lower values of community structure indicators. Still, both stations most influenced by coastal waters showed higher DO levels, lower nitrogen values and the highest species richness and diversity. These results demonstrate that environmental stress has an impact on the community structure of the inner harbor.

In our data, the Vitoria harbor channel estuarine system is characterized by a few abundant and many rare taxa. This also may be an indication of a low sampling number. Rare taxa (<5% coverage) seem to be an important component of the total richness of the community, since they often represented 80% of total richness.

We did not make any attempt to demonstrate causality between effluent and abundance patterns. The inner PI and PMI showed a greater abundance of taxa that tolerate anthropogenic stress, as the sponges *T. ignis* and *H. heliophila*. These species are generalists that can live in polluted environments such as bays and port areas (Muricy & Hadju 2006), and the genera they belong to have great adaptive plasticity (Carballo *et al.* 1996). Port terminals are usually built in sheltered areas such as coves, bays or estuaries. Routine port activities, besides dredging activity in the navigation channels, affect the composition and distribution of marine benthic communities through removal and suspension of sedimentary material, increasing the quantity of particulate matter in the water column (Angonesi *et al.* 2006).

In this study, the separation of the biota into two environmental systems was clear considering the environmental parameters (temperature, transparency, DO, nitrate and total nitrogen) and community indicators (richness, diversity and dominance), which were significantly different at the outermost stations. The inner portions of the access channel to the Vitória harbor are narrower than the outer ones, causing an increase in water velocity in the innermost portion of the channel (Mao *et al.* 2004). Thus, the particles suspended by dredging activities and maneuvering of ships in the Vitória harbor, located between the PI and the PMI stations, may be carried away to the outer portions. In fact, we had to temporarily interrupt some sampling surveys at the inner parts because the water visibility was low, a result of the high volume of suspended material from dredging activities. It is noteworthy that tidal currents can also transport suspended material. It is possible that the dredging activity mentioned above is correlated with certain tidal status, perhaps a low tide flow. Despite the proximity of the external stations to the open sea, the output channel of the Vitória Harbor goes into the Espírito Santo Bay (detail in Fig. 1). This spatial configuration shelters the site from strong currents coming from the Northeast, which could disperse the plume of the estuarine sediments and carry them out to sea.

In areas with higher sedimentation rates (percentage cover of sediment over the bedrock >50%) as in PME and PE, we recorded taxa with vertical growth such as the octoral *C. riisei*, the hydroid *D. disticha* and the bryozoan *S. cornigera*, or vagile species such as the echinoderms *E. brasiliensis* and *L. variegatus*. This morphological adaptation favors individuals in situations of intense sedimentation, because they can remain above the substrate to filter/capture food, or move to find food (Stevens & Connolly 2003).

Raimondi & Reed (1996) and Bishop *et al.* (2002) showed that ecological variables are not necessarily correlated with physical or chemical variables. However, we found some specific associations between the biotic and abiotic attributes in our data. The aggregate of bryozoans + hydrozoans and sponges were associated with the more estuarine conditions of the innermost stations, and *Carijoa* spp., *Didemnum* spp., and *Sertularia* spp. were associated with more coastal waters.

Dredging may alter the hydrological regimen, changing the biochemical characteristics of the system, and creating opportunities for the replacement of species (Driesch & Driesch 2001, Silva *et al.* 2004). Thus, long-term monitoring studies are necessary to evaluate the impacts that these activities promote on the local marine communities, and to diagnose whether changes in these communities' structure are the result of anthropogenic effects or whether correspond to natural variations of these populations (Pagola-Carte & Saiz-Salinas 2001, Widdicombe & Austen 2001).

The access channel of the Vitoria Harbor shows a spatial variation in the characteristics of the water mass and in the epibenthic community over a small scale (~3 km), with an heterogeneous distribution throughout the studied area. Similarly, at the Bilbao Harbor, in the northern part of Spain, Saiz-Salinas & Urkiaga-Alberdi (1999) concluded that the local epibenthic fauna was highly variable at a similar spatial scale (~3 km), and the distribution of organisms was significantly related to the local turbidity.

Our results indicate that the study area can be divided in two regions, one with estuarine characteristics, at the innermost stations, and another composed of coastal waters, at the outermost ones. The subtidal epibenthic community is distributed along this physical-chemical gradient. These characteristics resulted in two benthic assemblages, supporting the hypothesis of spatial variation. The main determinants were the environmental stress promoted by changes in the physicochemical parameters, and inorganic nutrients in the seawater surrounding the Vitoria Harbor, specifically at the innermost stations, where local dredging activities are frequent. An environmental monitoring system is clearly needed along the Vitória Harbor Channel. However, since the benthic populations may respond differently to disturbances at different spatial scales, attempts to quantify local impacts should involve further sampling on multiple spatial and temporal scales.

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